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ELECTRONIC NEWS-GATHERING: the effect of multipath propagation

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ELECTRONIC NEWS-GATHERING: THE EFFECT OF MULTIPATH PROPAGATION

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Summary

The use of u.h.f. or s.h.f. radio links for electronic news-gathering (ENG) has posed many problems in built-up areas. Presently the major obstacle is multipath propagation caused by reflection of the signal off the walls of buildings and other structures.

A series of tests was conducted in the centre of London in order to measure the multipath signal strengths and echo delays that could be expected on typical ENG transmission paths. The a.m. pulse system that was used gave results with greater definition than those provided by previous tests.

For each transmission path that was investigated different frequency bands (2·5 GHz and 12 GHz) and aerial polarizations were used. The results are presented in the form of photographs of video waveforms and received pulses, together with a tabulation of measured signal-strengths, video signal-to-noise ratios and values of echo signal-strength and delay. The results are analysed to show which factors affect the multipath performance of each link.

Issued under the authority of

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1. Introduction

Experiments are in progress concerning the use of radio links in the upper u.h.f. or the s.h.f. bands for Electronic News Gathering (ENG) in and around the centre of London. Tests with equipment using frequency modulation and operating in the 2·5 GHz and 12 GHz bands have yielded poor results from many proposed transmitting sites owing to a large degree of multipath propagation, even when the signal-to-noise ratio (s.n.r.) of the received signal would have been adequate for a news insert.*

Proposals have been made to use alternative methods of modulation on such links, for example digital video coding with the possibility of using special codes and error protection to reduce the multipath problem. The design of any new modulation system, however, requires a knowledge of the amplitudes and delays of the indirect-path signals with respect to the direct signal.

At first an attempt was made to use the 2T pulse transmitted in a video insertion-test signal to assess multipath effects. At the link receiver the intermediate frequency (i.f.) envelope was displayed on an oscilloscope and the depressions due to the 2T pulse and its echoes were measured. Unfortunately the use of frequency modulation (f.m.) in the link equipment meant that these depressions were very small compared with the amplitude of the i.f. signal, and the results so obtained were not conclusive.

A better method proved to be the use of amplitude modulation (a.m.) by short pulses, with a pulse modulator at the output of the link transmitter; the receiver i.f. envelope then consisted of pulses, due to the direct signal and its echoes. The displayed envelope was easier to interpret because the i.f. amplitude dropped to the noise level between the pulses.

The results of a series of tests using the a.m. pulse system will be presented. The equipment and operational techniques employed are described in outline, further details being available in the appendices.

2. Details of the tests

2.1. Transmitting and receiving sites

To simulate the conditions of a typical ENG link the transmitting equipment was carried in a modified Land-Rover vehicle and the transmitting aerials were mounted on its roof and were operated at a height of 3 m above ground level. The receiving equipment was housed at the top of a 60 metre office block** and the receiving aerials were positioned on the roof of the building. The transmitting vehicle was driven to ten selected transmitting sites, of which five yielded signal paths suitable for demonstrating the effect of multipath propagation. Results will not be presented for the other five sites because the received signals were either too low in level to allow accurate measurement, or too free of multipath effects to be of particular interest in the tests.

2.2. Equipment

The equipment used for the tests was a combination of standard BBC outside-broadcast link equipment and specialized equipment developed in Research Department. A list of the equipment can be found in Appendix 6.1. The test set-up is described in Appendix 6.2 and details of the modifications made to the standard link receivers can be found in Appendix 6.3.

The special component, the pulse modulator, was constructed in two forms, one for each frequency band.

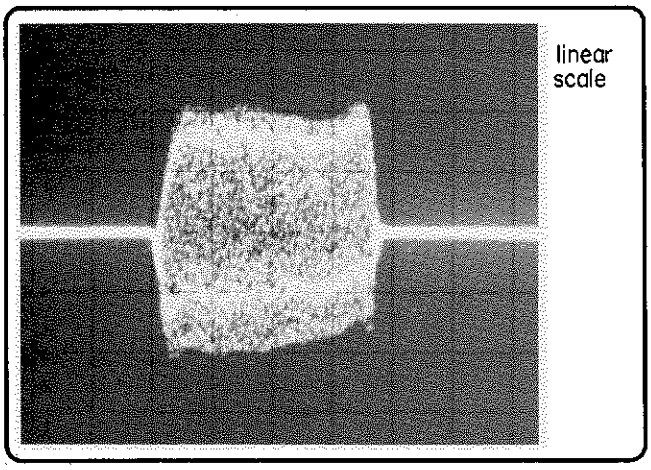


Fig. 1 - Shape of r.f. pulse, 10 ns/div.

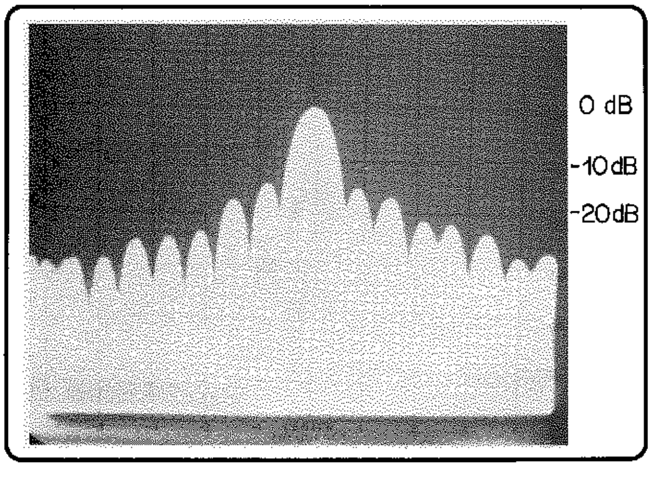


Fig. 2 - Spectrum of r.f. pulse, 50 MHz/div.

* A video s.n.r. of 34 dB (unweighted) is judged as just acceptable.

** Marsham Towers, North Block, Marsham St., Westminster (an office at present used by a Government Department).

The resulting radio frequency (r.f.) pulse shape is illustrated in Fig. 1, for the 2·5 GHz band modulator, and Fig. 2 shows the frequency spectrum of this pulse. It can be seen that the half-power points of the spectrum appear within a total spread of 30 MHz, the bandwidth of the link receivers. The 40 ns pulse length allows a spatial resolution of echoes down to 12 metres, assuming that no degradation of the pulse occurs in the receiver.

2.3. Operations

The operation of equipment used in the tests was handled mainly by personnel of the BBC O.B. Comms. Dept., under the supervision of members of Research Department. The procedure adopted for the tests is outlined in Appendix 6.4.

For 2·5 GHz the transmitting aerial was circularly polarized and the receiving aerial could be switched to respond to both circular polarizations or to linear vertical and horizontal polarizations. Linearly polarized aerials (vertical or horizontal) only could be used for the 12 GHz band at either end of the link owing to availability. For each transmission path used there were several options available:

(a) use of a direct (line of sight) path when possible, or the use of a reflected path

(b) use of the 2·5 GHz or 12 GHz band

(c) use of co-polarized or differently polarized aerials at each end of the link.

Each of these options was tried, and the results will be presented for those cases which showed results of interest.

3. Results

The results are presented in Table 1 and Figs. 3 to 15 which show the associated oscilloscope photographs. The quoted signal level was measured after the front-end of the link receiver (see Appendix 6.3) and is not the absolute received signal strength. The signal-to-noise ratio (s.n.r.) was measured at baseband using a video s.n.r. measuring set. Unless otherwise stated, the receiving aerial was operating in the same polarization mode as the transmitting aerial; this condition applied to most of the successful tests, in which other polarizations of the receiving antenna were found to degrade the signal.

4. Analysis of results

The oscilloscope photographs of the received pulses show the multipath 'echoes' as further pulses after the original one. Although the vertical axes in these photographs are linearly calibrated (as opposed to logarithmic) the multipath signal-strengths can be usefully expressed in

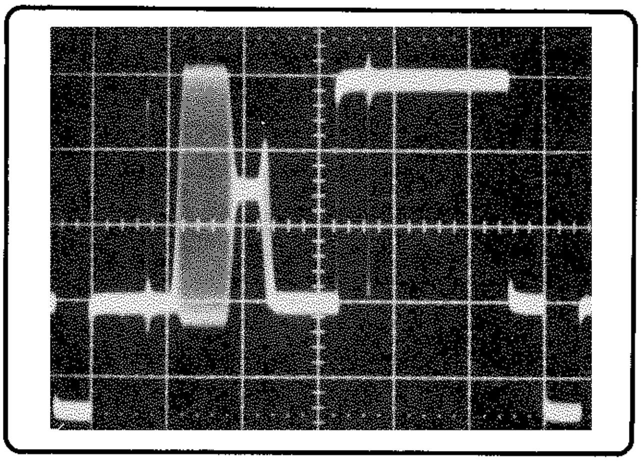
TABLE 1

Table of Echo Signal-Strengths and Delays

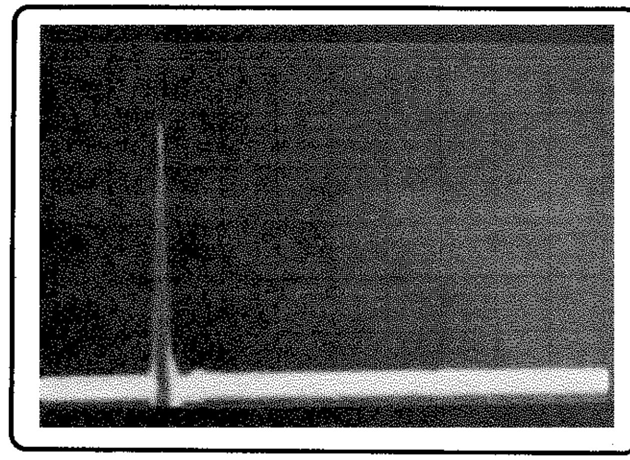
Test No.	Site	Frequency (GHz)	Signal level (dBm) (see Appendix 6.3)	Unweighted s.n.r. (dB)	First Echo		Second Echo		Third Echo	
					Relative strength (dB)	Delay (ns)	Relative strength (dB)	Delay (ns)	Relative strength (dB)	Delay (ns)
1	A	2·5	−42	40	−20	120	–	–	–	–
2	A	12·0	−23	52	−30	700	–	–	–	–
3	B	2·5	−24	53	–	–	–	–	–	–
4	B	2·5	−42	37	− 9	80	–	–	–	–
5	B	12·0	−46	26	–	–	–	–	–	–
6	B	12·0	−42	34	–	–	–	–	–	–
7	C	2·5	−47	32	− 2	80	− 4	550	–	–
8	C	2·5	−52	<20	− 1	100	− 8	1800	–	–
9	C	12·0	−40	36	−11	120	–	–	–	–
10	D	2·5	−37	48	−20	480	−10	780	−7	1100
11	D	12·0	−37	40	−14	900	–	–	–	–
12	E	2·5	−50	34	− 1	20	–	–	–	–
13	E	12·0	−37	40	–	–	–	–	–	–

Key to Locations of Sites

A – The Mall
B – Regency Street
C – Shell Building (near Festival Hall)
D – Parliament Square
E – South Bank



Received video waveform 10 μs/div.



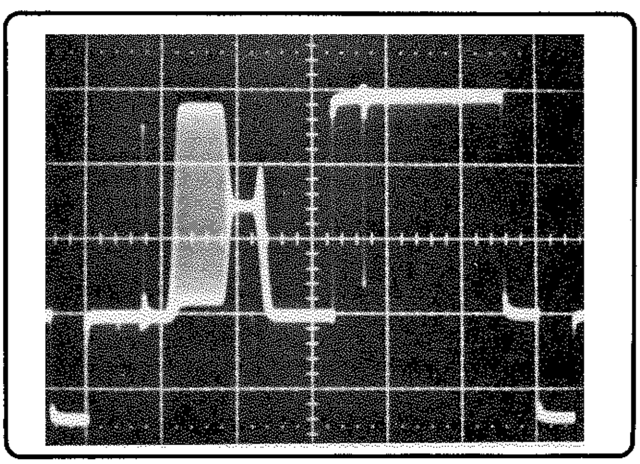
Received pulses 200 ns/div.

Fig. 3 - Test No. 1

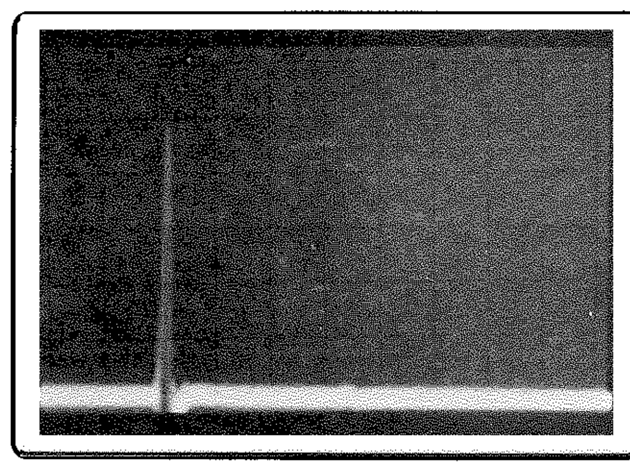
Line-of-sight path

Location	–	The Mall
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–42 dBm
Unweighted s.n.r.	–	40 dB

No useful signals were obtained on reflected paths.



Received video waveform 10 μs/div.



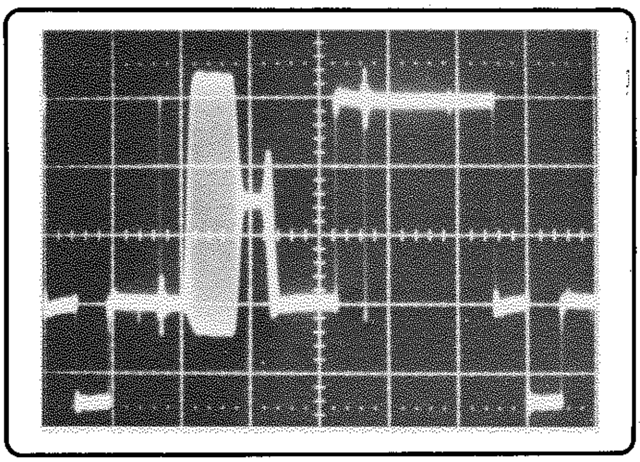
Received pulses 200 ns/div.

Fig. 4 - Test No. 2

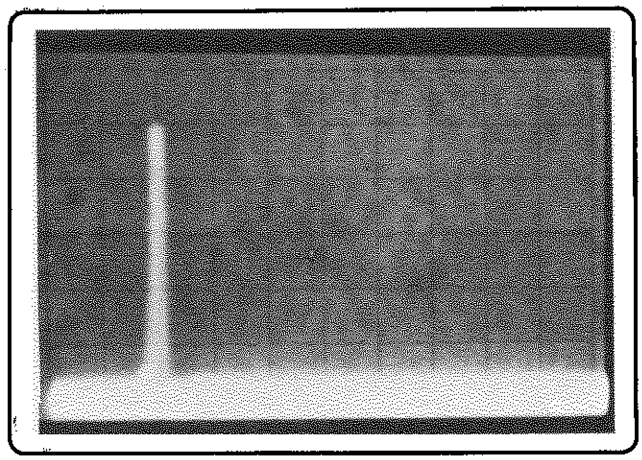
Line-of-sight path

Location	–	The Mall
Frequency band	–	12 GHz
Transmitted polarization	–	Horizontal linear
Relative signal level	–	–23 dBm
Unweighted s.n.r.	–	52 dB

No useful signals were obtained on reflected paths.



Received video waveform 10 μs/div.



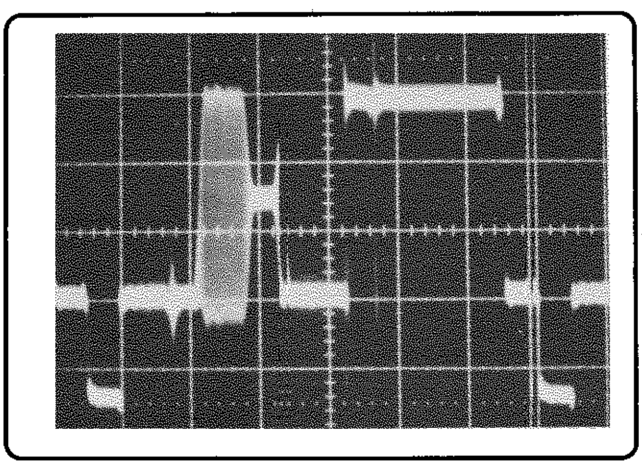
Received pulses 200 ns/div.

Fig. 5 - Test No. 3

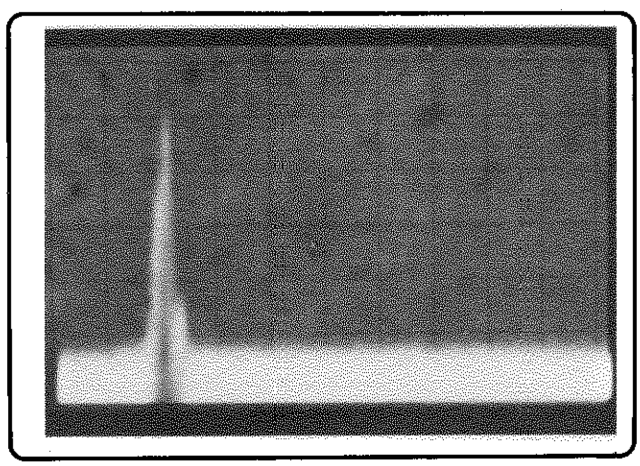
Reflected path

Location	–	Regency Street
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–24 dBm
Unweighted s.n.r.	–	53 dB

The signal was reflected from a large block of flats; no line-of-sight path was available. This path would not carry a 12 GHz signal.



Received video waveform 10 μs/div.



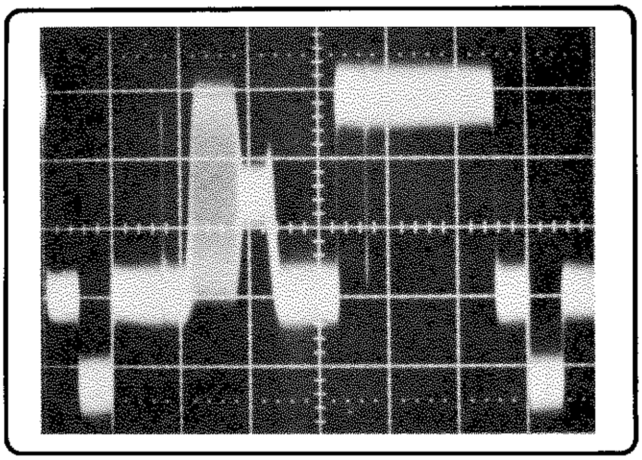
Received pulses 200 ns/div.

Fig. 6 - Test No. 4

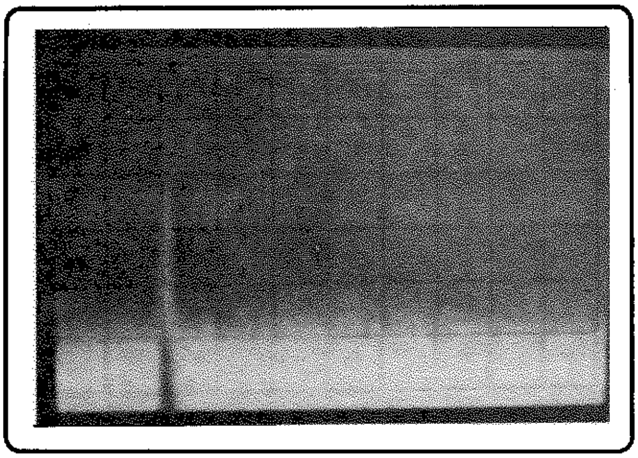
Reflected path

Location	–	Regency Street
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–42 dBm
Unweighted s.n.r.	–	37 dB

The signal was reflected from the New Scotland Yard Police building (N.S.Y.)



Received video waveform 10 μs/div.



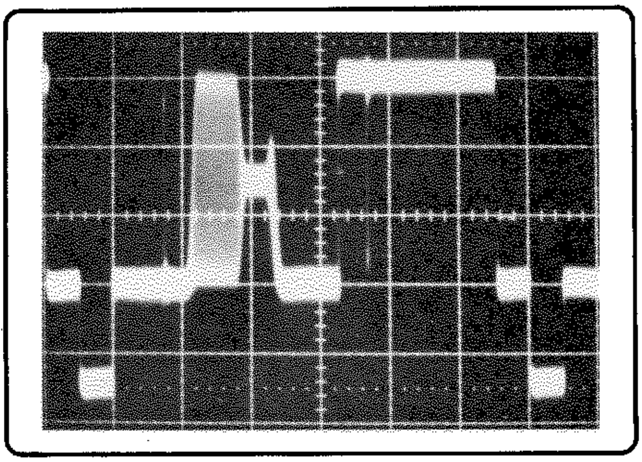
Received pulses 200 ns/div.

Fig. 7 - Test No. 5

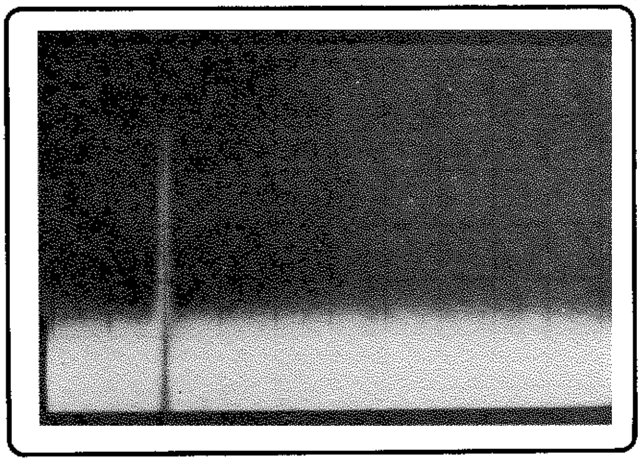
Reflected path

Location	–	Regency Street
Frequency band	–	12 GHz
Transmitted polarization	–	Horizontal linear
Relative signal level	–	–46 dBm
Unweighted s.n.r.	–	26 dB

The signal was reflected from N.S.Y.; no line-of-sight path was available.



Received video waveform 10 μs/div.



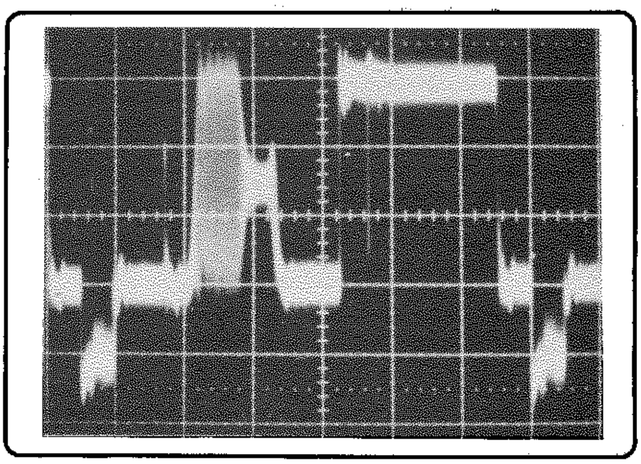
Received pulses 200 ns/div.

Fig. 8 - Test No. 6

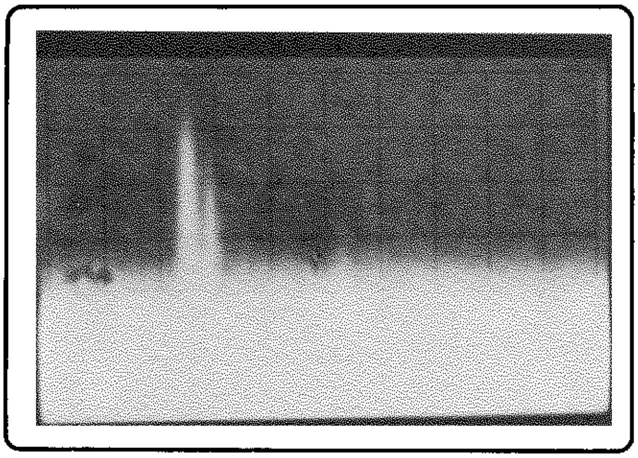
Reflected path

Location	–	Regency Street
Frequency band	–	12 GHz
Transmitted polarization	–	Vertical linear
Relative signal level	–	–42 dBm
Unweighted s.n.r.	–	34 dB

The signal was reflected from N.S.Y.



Received video waveform 10 μs/div.



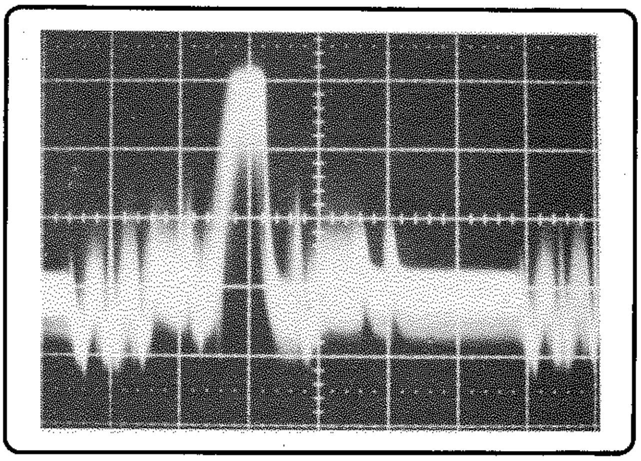
Received pulses 200 ns/div.

Fig. 9 - Test No. 7

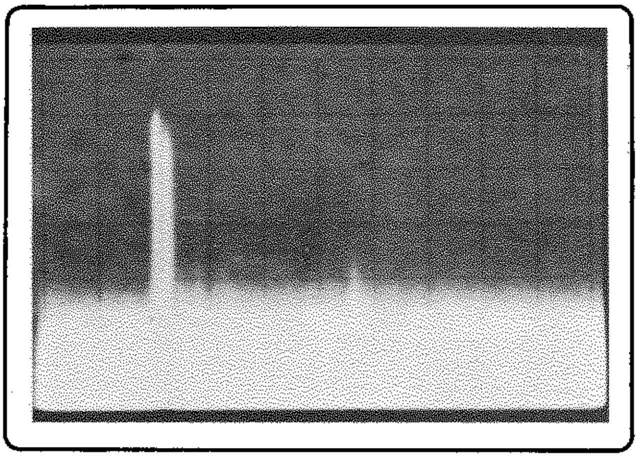
Line-of-sight path

Location	–	Shell building (near Festival Hall)
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–47 dBm
Unweighted s.n.r.	–	32 dB

The signal was reflected from the Shell building as well as travelling on the direct path, i.e. the building was slightly offset from the direct path.



Received video waveform 10 μs/div.



Received pulses 500 ns/div.

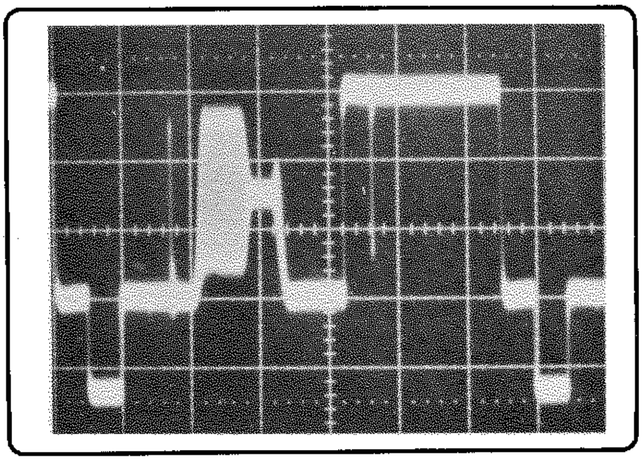
Fig. 10 - Test No. 8

Line-of-sight path

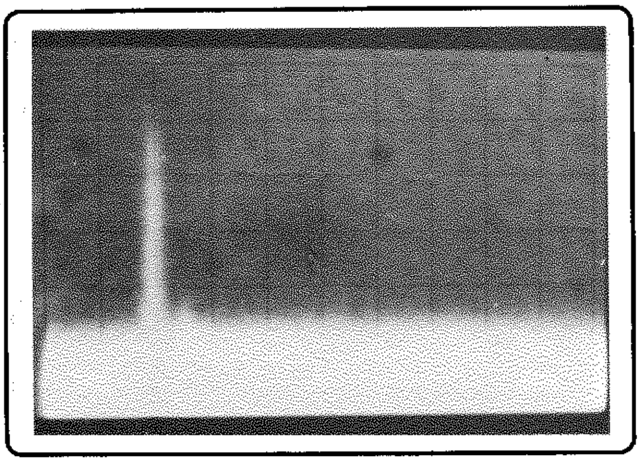
Location	–	Shell building
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–52 dBm
Unweighted s.n.r.	–	< 20 dB*

The signal was reflected from the Shell building as before and the transmitting and receiving aerials *were operating in opposite circular polarization.*

* The s.n.r. measuring set measured down to 20 dB only.



Received video waveform 10 μs/div.



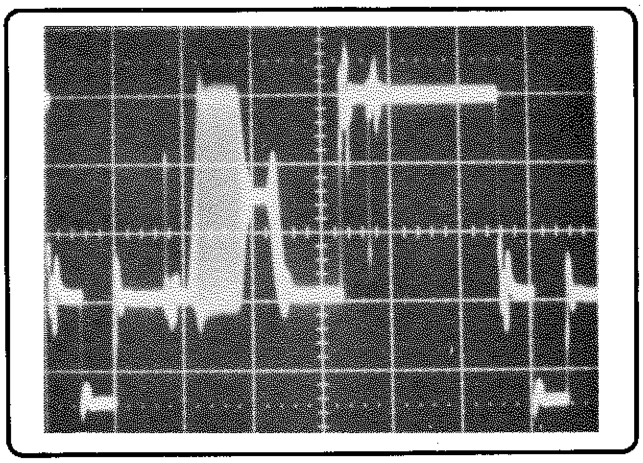
Received pulses 200 ns/div.

Fig. 11 - Test No. 9

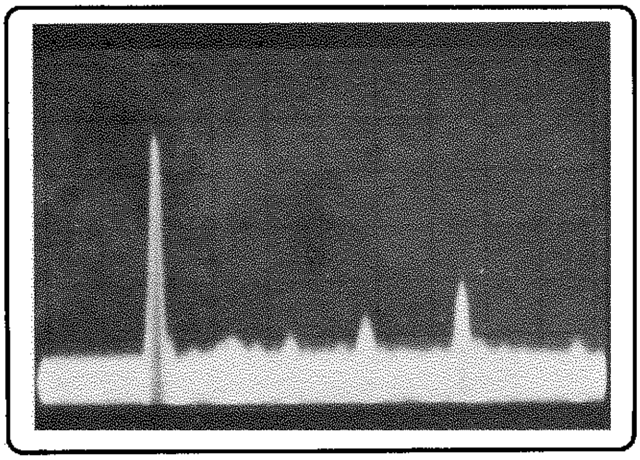
Line-of-sight path

Location	–	Shell building
Frequency band	–	12 GHz
Transmitted polarization	–	Vertical linear
Relative signal level	–	–40 dBm
Unweighted s.n.r.	–	36 dB

The signal was reflected from the Shell building. Other polarizations and reflected paths degraded the signal.



Received video waveform 10 μs/div.



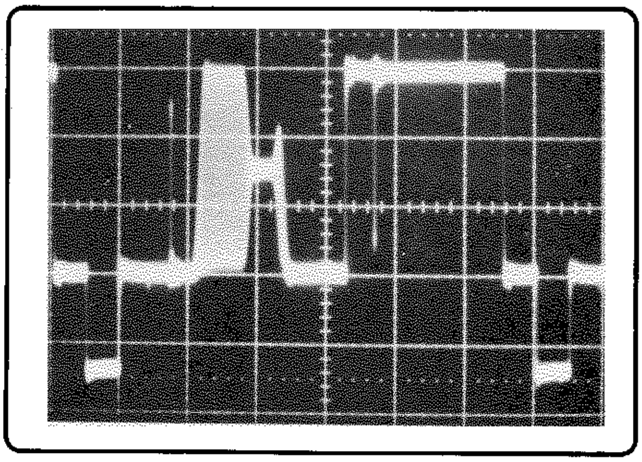
Received pulses 200 ns/div.

Fig. 12 - Test No. 10

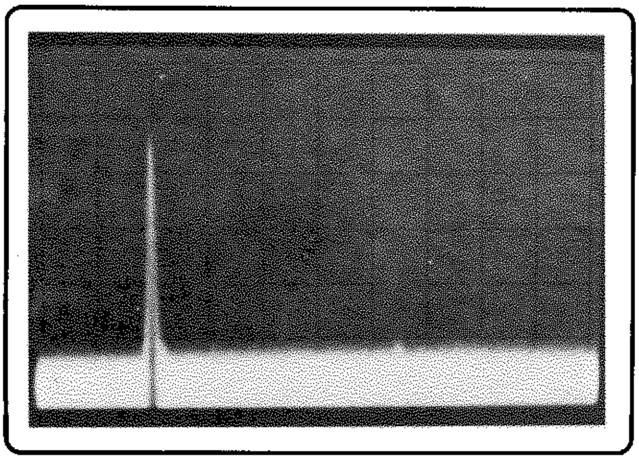
Line-of-sight path

Location	–	Parliament Square
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–37 dBm
Unweighted s.n.r.	–	48 dB

No useful signals were obtained on reflected paths or with other polarizations.



Received video waveform 10 µs/div.



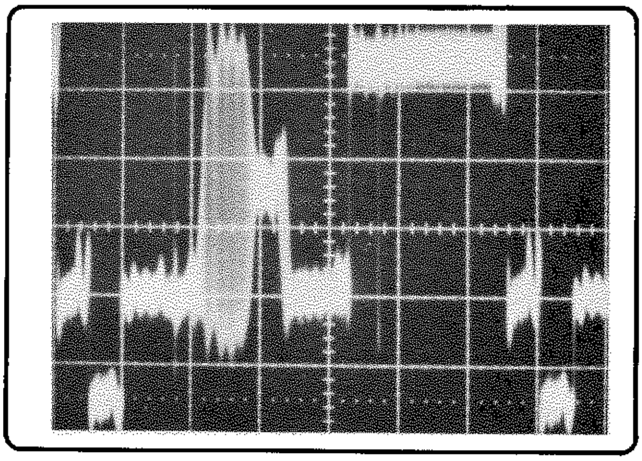
Received pulses 200 ns/div.

Fig. 13 - Test No. 11

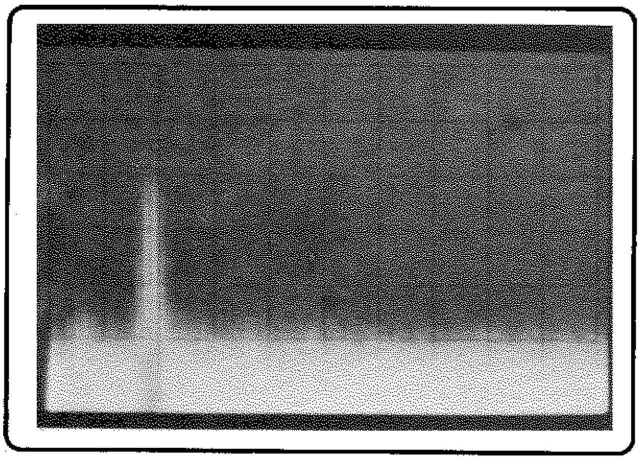
Line-of-sight path

Location	–	Parliament Square
Frequency band	–	12 GHz
Transmitted polarization	–	Vertical linear
Relative signal level	–	–37 dBm
Unweighted s.n.r.	–	40 dB

No useful signals were obtained on reflected paths. Other polarizations degraded the signal.



Received video waveform 10 µs/div.



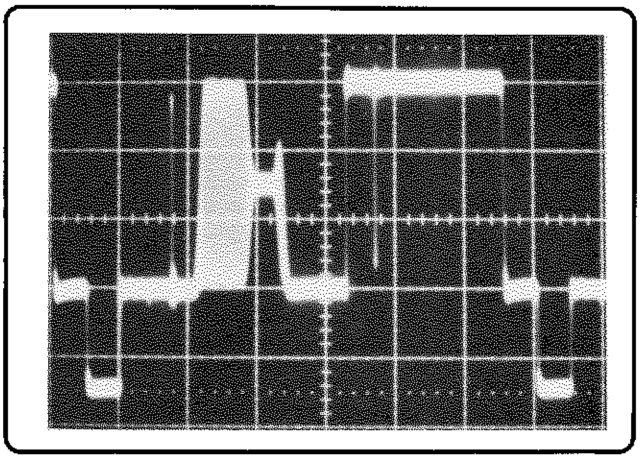
Received pulses 100 ns/div.

Fig. 14 - Test No. 12

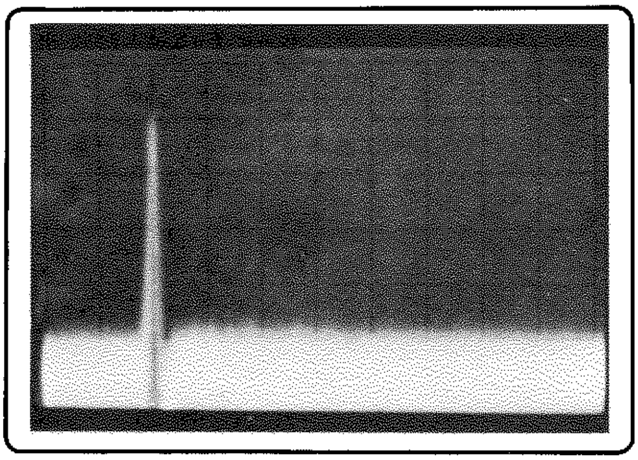
Reflected path

Location	–	South Bank
Frequency band	–	2·5 GHz
Transmitted polarization	–	Circular
Relative signal level	–	–50 dBm
Unweighted s.n.r.	–	34 dB

The signal was reflected from the Vickers building. Other polarizations and reflected paths degraded the signal. This path would not successfully carry a 12 GHz signal. No line-of-sight path was available.



Received video waveform 10 μs/div.



Received pulses 200 ns/div.

Fig. 15 - Test No. 13

Reflected path

Location	–	South Bank
Frequency band	–	12 GHz
Transmitted polarization	–	Vertical linear
Relative signal level	–	–37 dBm
Unweighted s.n.r.	–	40 dB

The signal was reflected from the Houses of Parliament. Other reflected paths degraded the signal. This path would not carry a 2·5 GHz signal without severe degradation.

decibels with respect to the strength of the first, original pulse. In addition, the delay of each echo after the original pulse can be read off the horizontal axis. These measurements are presented in Table 1 along with the relative signal level (as before) and the video s.n.r.

From this table it can be seen that echo-signal-strengths as great as –1 dB relative to the original signal are possible. The oscilloscope photographs of video waveforms for these cases show that a large degree of distortion is introduced.

Several inferences can be made from the results regarding the use of the two alternative frequency bands and alternative polarizations:–

(a) In general, where a 12 GHz link was possible, it resulted in less multipath distortion than 2·5 GHz. This is probably caused by two factors. Firstly, the wavelength is shorter on 12 GHz, so the directivity of the aerials is greater for this frequency than for 2·5 GHz, i.e. the half-power beamwidths of the 12 GHz transmitting and receiving paraboloid aerials are $1{\cdot}4^\circ$ and $2{\cdot}8^\circ$ respectively, whereas the 2·5 GHz aerials have azimuthal beamwidths of $6{\cdot}8^\circ$ and 90°.* With the correspondingly narrower beamwidths there will tend to be fewer significant reflected signals.

Secondly, the shorter wavelength will lead to more scattering on reflection by buildings with rough surfaces (e.g. recessed windows) and, therefore, more loss on reflected paths.

(b) All but one of the 12 GHz paths (Test No. 2) gave superior performance with vertical polarization. In the cases where a reflected path was used for the main signal this result is likely to be due to the fact that for a specular reflection in the horizontal plane, the reflection coefficient of a wall (of a building) will be greater for a vertically polarized wave, i.e. the electric field is perpendicular to the plane in which the reflection is taking place. This is exemplified by a comparison of Tests 5 and 6.

(c) Tests No. 7 and 8 show the effect of cross-polarizing the circularly-polarized aerials, but in this case the received signal level was too low for the f.m. system to function; hence the poor s.n.r. However, the fact that one strong reflection is exchanged for another shows that in a few very special cases cross-polarization could be used to reduce multipath distortion.

Several inferences can also be made regarding the strengths and delays of echo-signals:–

(d) When very strong first echoes were received ($<$ 3 dB down) they appeared to be delayed by less than 100 ns. This would agree with the previous comments

* The 90° aerial is of the horn type.

about the beamwidth of aerials, although the maximum delay would, of course, depend on the distance between transmitter and receiver.

(e) Long delayed echoes (delay > 1000 ns) only appear on the 2·5 GHz band. This would be a function of beamwidth as before, although the use of a power amplifier with the 2·5 GHz transmitter might have some bearing on the results, i.e. the noise performance of the 12 GHz set up was not quite as good as for 2·5 GHz and some low-level echoes must have been masked by noise.

5. Conclusions

It can be concluded that the multipath performance of a typical ENG radio link is heavily influenced by the choice of frequency band, and to a lesser extent by the type of polarization used. Any digital-coding or other modulation system which is proposed to reduce the multipath distortion will have to cope with echoes as strong as −1 dB with respect to the original signal, and with delays up to 1800 ns for strengths down to −8 dB.

The results of these tests are in no way conclusive and echo strengths of −0 dB must be possible when using a reflected path with two 'parallel' reflections.

The overall conclusion must be that to operate ENG successfully with microwave radio links a lot of care will be needed in choosing the transmitting site and the transmission path, or a portable mast will be needed for the transmitting aerial. Without these precautions in setting up the link, multiple-hop techniques will be necessary, unless a transmission system could be designed to reduce the effect of echo signals. At present, no practical television transmission system has been put forward that is claimed to be significantly better than f.m. under multipath conditions.

6. Appendix

6.1. Equipment used for the tests

6.1.1. Transmitting equipment

2·5 GHz

2560 MHz MAL* link transmitter
2560 MHz MAL 10W power amplifier
3 dB attenuator
Research Department 2·5 GHz PIN diode modulator
1·2 metre Nurad dish with circularly polarized feed

12 GHz

12·05 GHz MAL link transmitter
Research Department 12 GHz PIN diode modulator
1·2 metre MAL dish with V or H plane polarized feeds

Auxiliary equipment

141 MHz sound link receiver
141 MHz collinear aerial
Video pulse and bar generator
Radiotelephones

* MAL stands for Microwave Associates Ltd., the manufacturer.

6.1.2. Receiving equipment

2·5 GHz

2560 MHz MAL link receiver
Nurad Horn aerial with switchable polarization (vertical or horizontal plane polarization, left or right-hand circular polarization)

12 GHz

12·05 GHz MAL link receiver
0·6 metre MAL dish with V or H plane-polarized feeds

Auxiliary equipment

141 MHz sound link transmitter
141 MHz dipole aerial
20 kHz tone source
Video signal-to-noise ratio measuring set
Hewlett Packard 183 oscilloscope
Hewlett Packard Spectrum Analyser (0-1100 MHz)
0—70 dB adjustable r.f. attenuator
Polaroid camera for oscilloscope
Prowest TV picture monitor
Radiotelephones

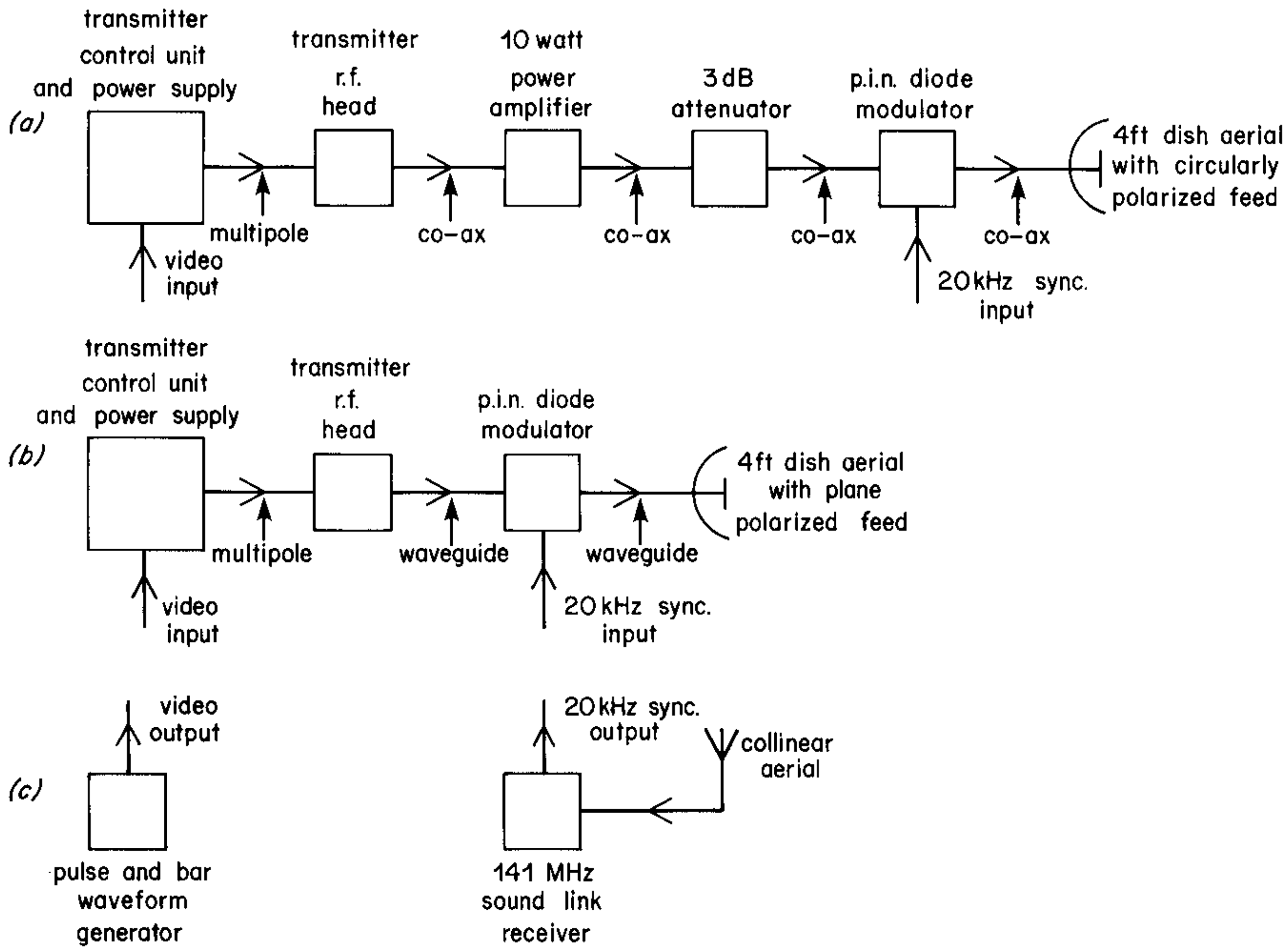


Fig. 16 - Transmitting equipment

6.2. Details of the test set up

6.2.1. Transmitting equipment

Fig. 16 shows the interconnection of the transmitting equipment used for the tests.

The 2·5 GHz link transmitter was connected to a 10 watt R.F. power amplifier and then to the input of the P.I.N. diode pulse modulator via a 3 dB attenuator as shown in Fig. 16(*a*). It was found necessary to limit the R.F. input to the modulator to 5 watts to prevent damage to the P.I.N. diodes. The output of the modulator was connected to the dish aerial mounted on the roof of the Land Rover.

The 12 GHz link transmitter was connected to the 12 GHz P.I.N. diode modulator and then to the 12 GHz dish aerial as shown in Fig. 16(*b*). A power amplifier was not available for operation in this band.

The auxiliary equipment shown in Fig. 16(*c*) consisted of a video pulse-and-bar waveform generator for assessing the video performance of the link, and a 141 MHz sound link receiver with a collinear aerial mounted on the roof of the Land Rover. A 20 kHz tone being sent to this receiver was taken from its audio output to the trigger input of the P.I.N. diode modulator in use (2·5 GHz or 12 GHz).

6.2.2. Receiving equipment

Fig. 17 shows the interconnection of the receiving equipment used for the tests.

The 2·5 GHz link receiver was mounted on the roof of the tower block at the receiving site, fed by the horn aerial as shown in Fig. 17(*a*). The i.f. and video outputs were fed to the auxiliary equipment in an adjacent room.

The 12 GHz link receiver was mounted in the same place and fed by a dish aerial with a waveguide feed as shown in Fig. 17(*b*).

The auxiliary equipment shown in Fig. 17(*c*) consisted of a spectrum analyser connected to the i.f. output of the receiver in use, an oscilloscope connected to the i.f. or video output, and a T.V. picture monitor and video signal-to-noise ratio measuring set, both connected to the

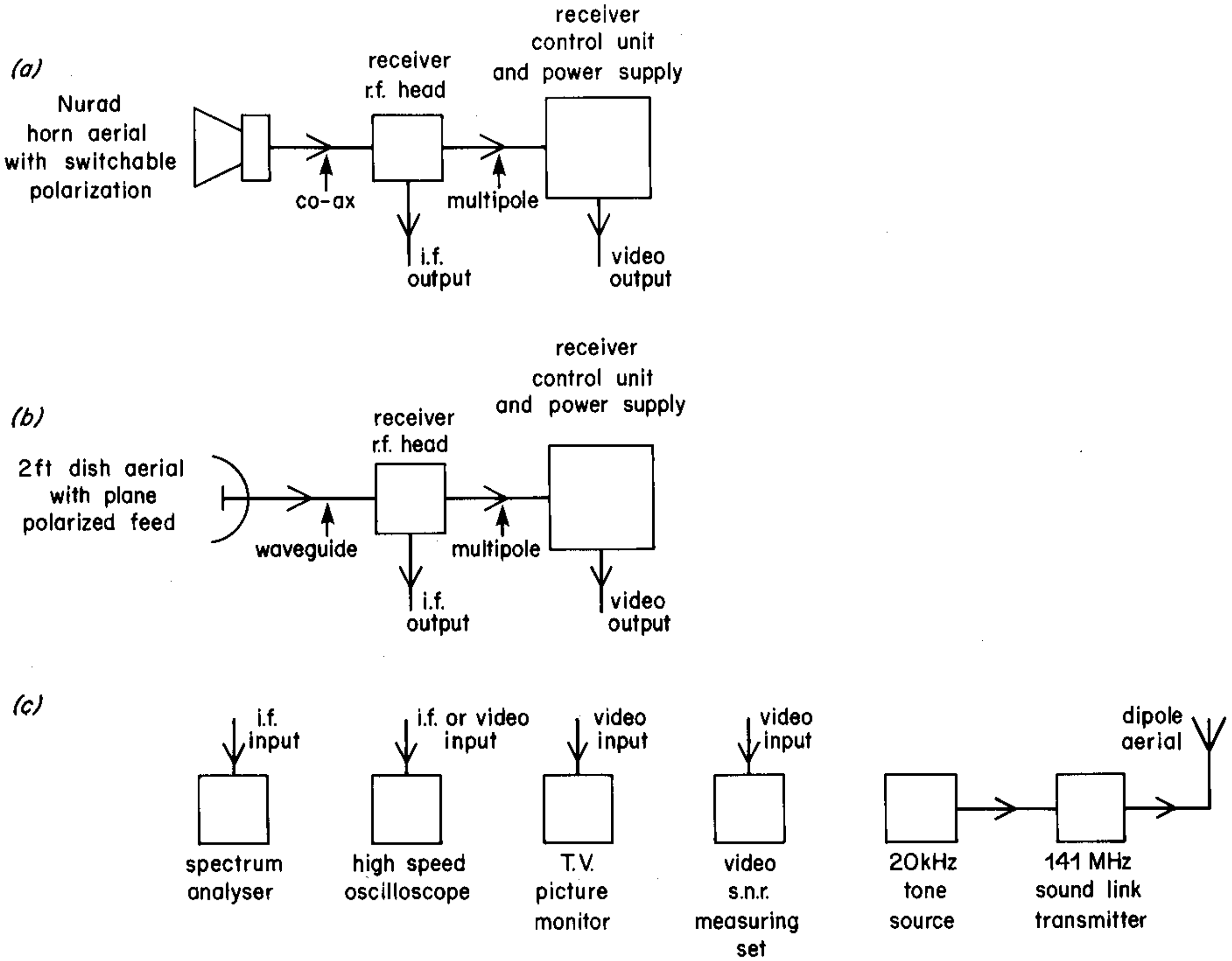


Fig. 17 - Receiving equipment

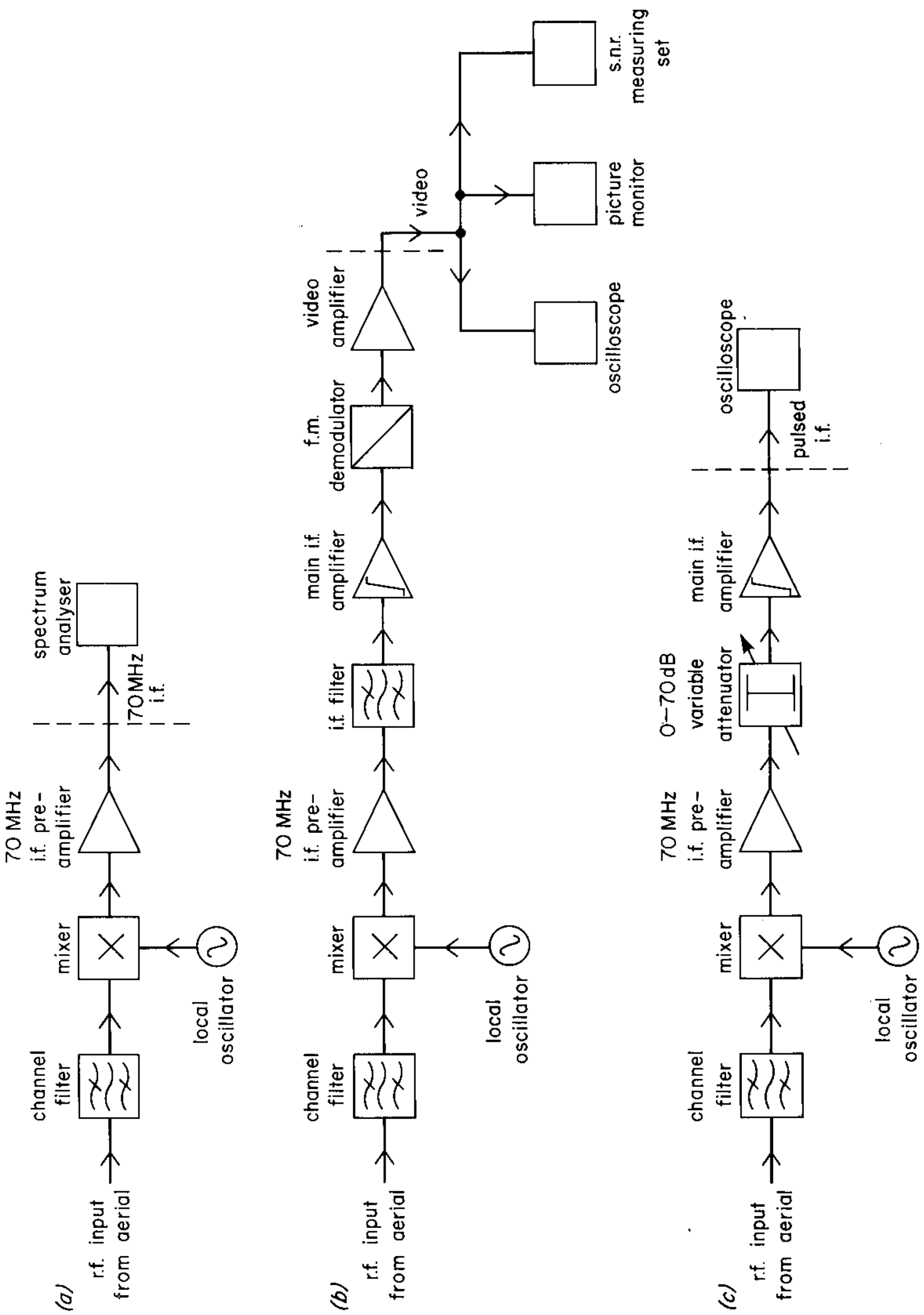


Fig. 18 - Modifications made to link receivers

video output. A 20 kHz tone source was fed to the modulation input of a 141 MHz sound link transmitter to provide a synchronizing time-base for the pulse modulators at the transmitting site. The output of the transmitter was fed to a dipole aerial. This system permitted remote control of the pulse repetition frequency (p.r.f.) from the receiving site, where the measurements were being made.

6.3. Modifications to the link receivers

Provisions were made to alter the connections to the i.f. outputs within the r.f. head units of the link receivers. Three different connections were used as follows:—

Connection No. 1 — The output of the i.f. pre-amplifier was fed down to the spectrum analyser as shown in Fig. 18(*a*). This aided the acquisition of signals and permitted the measurement of the carrier power level of the signal arriving at the receiver. This connection was not affected by automatic gain control (a.g.c.).

Connection No. 2 — The wiring of the r.f. head unit was returned to its normal state, shown in Fig. 18(*b*), so that measurement of video s.n.r. could be made, using full a.g.c. and limiting (provided by the main i.f. amplifier). The 12 GHz r.f. head unit did not contain an i.f. band filter.

Connection No. 3 — The output of the main i.f. amplifier was fed down to the high-speed oscilloscope (HP183) for pulse measurements, as shown in Fig. 18(*c*). The i.f. band filter was bypassed to prevent ringing on the pulses; the bandwidth of the main i.f. amplifier was about 30 MHz. The i.f. mute circuit was disconnected. The transmitted pulses were of 40 ns duration, occurring at 20 kHz p.r.f. so the average signal level was very low. This meant that the a.g.c. would be inoperative, and because the peak signal level could be quite high during a pulse there was a probability of clipping occurring in the last stages of the main i.f. amplifier. This would invalidate any measurement of relative amplitudes of returned pulses and echoes, so an adjustable attenuator was interposed between the output of the i.f. pre-amplifier and the input of the main i.f. amplifier. On each occasion, before measurements were made, this attenuator was adjusted to bring the i.f. stages just out of clipping.

6.4. Test procedure

For each transmitting site the following order of events was adopted:—

1. The 2·5 GHz equipment was rigged with Connection No. 1.
2. The aerials were panned at both ends of the link to acquire signals.
3. The aerials were fine-panned to obtain maximum signal strength.
4. The pulse-and-bar generator was connected and with Connection No. 2 the video waveform was photographed.
5. Video was terminated at the transmitter and at the receiver the s.n.r. was measured.
6. The pulse modulator was switched on, and with Connection No. 3 the attenuator was adjusted for no clipping.
7. The received pulses were photographed.
8. The aerial polarizations were changed and the aerials were panned to investigate other possible paths. If one was found step 3 was returned to.
9. The 12 GHz equipment was rigged with Connection No. 1.
10. Steps 2 – 8 were followed.
11. The transmission equipment was de-rigged and moved to the next site.

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